SELF-CONSISTENT DATA ANALYSIS OF THE PROTON STRUCTURE FUNCTION G_1 AND EXTRACTION OF ITS MOMENTS

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A reanalysis of all available world data on the longitudinal asymmetry $A_{\|}$ is presented. The proton structure function g_1 was extracted within a unique framework of data inputs and assumptions. These data allowed for a reliable evaluation of moments of the structure function g_1 in the Q^2 range from 0.2 up to 30 GeV^2. The Q^2 evolution of the moments was studied in QCD by means of the Operator Product Expansion (OPE).

1. Introduction

One powerful tool to study nucleon structure is based on the Operator Product Expansion (OPE) technique. It offers a simple representation of the structure function moments in terms of so called "twists". Twists are $1/Q^2$ power terms in the Taylor expansion of the product of two hadronic currents separated by a small distance $\sim 1/Q^2$. The first term, twist-2 or "leading twist", contains information on individual parton distributions. This term expresses the asymptotic freedom of the nucleon constituents. The higher twist terms, therefore, imply an interaction among partons inside the nucleon. Understanding of this interaction, which can shed light on the puzzle of confinement, is the main goal of the present analysis.

2. Data analysis

The structure function g_1 is not directly measured in most experiments on polarized lepton scattering. Some experiments[1] can extract it directly from a combined measurement of the longitudinal and transverse asymmetries, but even these experiments demand some additional input on the spin averaged structure function, F_1, and the ratio of longitudinal to transverse photoabsorbtion cross sections, R. Each experimental collaboration typically chooses its own parameterizations for unmeasured quantities in the extraction of the structure function g_1 (see Table 1). The difference

Table 1. Parameterizations used in different experiments to extract g_1 and calculate its low-x extrapolation; ^{a} indicates the resonance region, ^{b} DIS, ^{c} $x < 0.003$.

Exp.	A_2	R	F_2	low-x
E130[2]	0	0.1^a 0.25^b	QCD-fit[14]	$A_1 = 0.94\sqrt{x}$
EMC[3]	0	QCD-fit[10]	QCD-fit[15]	$A_1 =$ $1.025x^{0.12}(1 - e^{-2.7x})$
E143[1]	meas.	R1990[11]	NMC-fit[16]	$g_1 = const$
SMC[4]	0	R1990[11] QCD-fit[12 c]	NMC-fit[16]	QCD-fit[19]
E155[5]	meas.	R1998[13]	NMC-fit[16]	NLO-fit[5]
HERMES[6]	0.06^a $\frac{0.53x}{\sqrt{Q^2}}{}^b$	0.18^a R1990[11 b]	Bodek[17 a] NMC-fit[16 b]	Bianchi and Thomas fit[20]
CLAS[7]	MAID[a] WW[8 b]	R1998[13]	JLab[18 a] NMC-fit[16 b]	fit to world data[21]

between these parameterizations yields a significant uncertainty in the obtained g_1 as shown in Fig. 1 for the same set of data points extracted according to E130, HERMES and CLAS procedures. Furthermore, the different low-x extrapolations lead to an uncertainty in the first moment; for example, at $Q^2 = 5$ GeV^2 the relative difference between a QCD-fit[22] and constant (Regge) behavior is about 3%. In order to resolve this diversity of assumptions in combining all of the world data, we started from the very beginning. The longitudinal asymmetries of the proton $A_\parallel$ measured in experiments[23,2,1,5,3,4,6,7] have been collected in a database as a function of x and Q^2. In order to extract the structure function g_1, we defined a fixed set of parameterizations for all unmeasured quantities, which we find to be most up to date.

To describe the asymmetry A_2, we combined the Wandzura and Wilczek (WW)[8] approach with a resonance contribution. The resonance contribution is calculated based on the electromagnetic helicity amplitudes $A_{1/2}(Q^2$ and $S_{1/2}(Q^2)$ obtained in a Constituent Quark Model[24] for 14 main res-

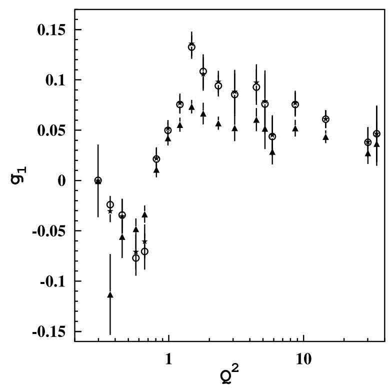

Figure 1. Proton structure function g_1 as a function of Q^2 at $x = 0.47 - 0.53$: empty circles indicate g_1 extracted under the assumptions used by the CLAS collaboration, triangles show g_1 based on E130 inputs and stars represent the HERMES approach.

onances. The background under the resonances and the entire A_2 in the DIS is described by the WW relation. Inclusion of Target Mass Corrections (TMC) in the WW approach turned out to be very important. Even at relatively large $Q^2 \approx 5$ GeV^2, inclusion of the TMC explained deviations between WW and E155x data[25] as shown in Fig. 2. This becomes understandable if we note that A_2 does not carry a leading twist contribution. In the resonance region, the model agrees very well with all available and preliminary experimental data and a phenomenological model[9].

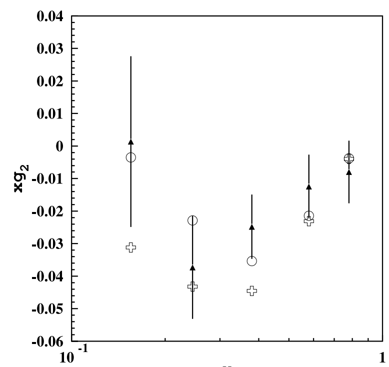

Figure 2. Comparison of the structure function xg_2 measured by E155x at $7 < Q^2 < 18$ GeV^2 to WW (empty crosses) and WW including TMC (circles).

For the ratio $R(x, Q^2)$ we use a new parametrization[26], which is adapted to the low-Q^2 and large-x region, and smoothly interpolates to the earlier parameterization of the deep inelastic region[13]. This parameterization uses all published and preliminary[26] data in the resonance region.

The F_2 structure function and the inclusive electron scattering cross section are well established experimentally with rather dense kinematic coverage. There is no need to rely on any particular parameterization. We used all world data on the F_2 structure function and inclusive cross sections[27] (when available) to interpolate between the closest F_2 points to each $A_\parallel$ measurement. This way we can strongly reduce the systematic uncertainty and the calculation of the statistical and systematic errors propagated from F_2 to g_1 becomes straightforward.

The extracted structure function g_1 was then combined in Q^2 bins and integrated by a numerical method over x within each bin. The contribution from the interval between the lowest measured point in x and $x = 0$ was then estimated according to various parameterizations of the structure function g_1. The parameterization based on Regge phenomenology[28] was chosen to provide the mean value of the extrapolated integral, while two others were used for an estimate of the systematic error.

3. Results and Discussion

Moments of the proton structure function g_1 were obtained from all world data on the longitudinal asymmetry $A_\parallel$. These moments were analyzed in terms of QCD and the results have been presented elsewhere[29]. We point out the main new features of the present analysis:

- the world data on the longitudinal asymmetry $A_\parallel$ are analyzed within an unique framework, based on a fixed set of inputs;
- a new model of A_2 improved agreement with the DIS data, through inclusion of TMC; for the first time the resonance contribution to A_2 was modeled in detail for a totally inclusive final state;
- recent data on the ratio R in the resonance region improved the extraction precision of g_1 and it's moments;
- spin-averaged cross sections, necessary for the g_1 extraction, were obtained directly from experimental data, avoiding large, model dependent uncertainties and making the error propagation straightforward.

The analysis showed important issues that can be addressed in future experiments and theoretical articles:

- knowledge of the transverse asymmetry A_2 in the resonance region is important, but still poor. Future and on-going experiments on A_2 should allow for a better determination of g_1 in this region;

- the low-x extrapolation contribution to the first moment is sizable (about 10%) and more experimental data are needed here (see COMPASS[30]);
- for a precise extraction of the higher moments more data at large x and $Q^2 > 2.5$ GeV^2 can be provided by Jefferson Lab now and after its upgrade to 12 GeV;
- the higher twist terms of OPE have been calculated only within some models and for a few moments. A direct QCD prediction, e.g., from lattice calculations, would motivated precise higher twist extractions from the data and allow a direct interpretation of the results. This also would represent an unique test of non-perturbative QCD predictions.

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